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ABSTRACT

A new concept, relativistic operations, seems to provide a link between Piagetian theory, information processing theory, logical thought in the new physics, and the nature of adults' problem solving in everyday social situations. Relativistic operations are logical, cognitive operations which can be used as a system to relate, order, and select as more useful one of the many mutually contradictory but "true" formal operational systems. In terms of Piagetian theory they are a post-formal level of thought processing; in information processing terms these operations mainly determine what is included or excluded in "problem-space" by the problem solver. Relativistic operations make possible the analysis of such complex relations as interpersonal relations. To test the assumption that these operations are present in the thinking of mature adults, male and female volunteers (N=79) aged 26-89 responded to written stimulus problems which demanded combinatorial reasoning with 2 or 3 variables. Responses were scored for the presence or absence of real-life formal operations as well as the presence or absence of relativistic operations. The results supported the assumption that relativistic operations seem to be used by many mature adults in logical problem solving. (WAS)

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Do Adults Use a Post-Formal "Theory of Relativity" to Solve Everyday Logical Problems?

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Paper presented as part of a symposium "On Missing Links: Interfaces Between Cognitive Research and Everyday Problem Solving", J. Cavanaugh & D. Kramer, Chairs. Gerontological Society, Boston, 1982.

In this symposium we have promised to search for "missing links" between cognitive research and everyday adult problem solving. Sometimes a missing link can be found if familiar questions are posed in different ways. In so many areas of science, as Kuhn points out, the missing piece, the one that gives a whole new interpretation to the issue, is right there all the time, but is overlooked. Then a conscious reconceptualization takes place, sometimes a sudden one, and the whole system changes. The missing link is discovered through conscious reconceptualization. I would like to suggest today that the missing link between cognitive research and everyday problem solving may involve examination of the act of reconceptualization itself.

Today I'll ask you to do a reconceptualization of your own, and to think about the act of reconceptualization itself. When a problem is being solved, how does reconceptualization take place at all? What leads to the decision to reconceptualize a problem? What kinds of skills make it possible for us to, so to speak, "jump out" of a mode of processing, make processing decisions (i.e., reconceptualizations), and "jump back" to continue processing in a reconceptualized way? What kinds of rules do we use to make decisions about which of the possible reconceptualizations to use or how to "jump in" or "out" of the system? What kinds of rules do we use to make decisions about which decision rules are permissible in reconceptualizing?

And, does the process involved in all this reconceptualization constitute some unique organization of information processing skills or logical operations that does link cognitive research and everyday problem solving in a new way? The answer to this last question appears to be a tentative "yes". There appears to be a unique organization of logical operations and information processing skills that link cognitive research and everyday problem solving in a new way. These operations and skills are very much involved with the reconceptualization process which takes place before or while a problem is being solved.

In this paper I would like to make only three points. First, a qualitatively unique set of skills and operations for reconceptualization--which I will call "relativistic operations"--seems to provide many of the missing links for which we are looking. Second, adults do use these skills to solve everyday logical problems, especially problems involving social settings. Third, in information processing terms, these operations mainly determine what is included or excluded in so-called "problem space" by the problem solver. These ideas also are more fully expressed in an article (Sinnott, 1981), and in a chapter to be published this year by Praeger in a book on the proceedings of the Harvard Symposium on Postformal Operations (Sinnott, in press).

What Led to the Idea of Relativistic Operations?

Relativistic operations is my term for a unique set of information processing skills and logical operations. They

appear postformal in Piagetian terms. I was led to examine these abilities by a number of ideas, some of which were theory-based and some data-based. For example, Piaget's theory of intellectual development had little to say pro or con about the existence of a postformal stage of development. There was no reason to assume that structures more complex than formal operations would not be found, if we looked. I had to ask myself, what would fill this theoretical gap? My brainstorming and reasoning was as follows. If Piaget's formal operations stage is an analog of scientific thought, and of the logical positivism and propositional reasoning that underlies scientific inquiry in chemistry or Newtonian physics, what sort of analog would reach beyond that to describe even more complex reasoning? The "new" physics of Einstein and quantum theory came next in the realm of physics and provided a more complex logical analog that subsumed the logic of Newtonian physics. The kind of logical thought which permits understanding of "new physics" concepts is a relativistic, self-referential logic. So, what might a postformal Piagetian stage contain? Relativistic, self-referential operations which could organize formal operations, as the general laws of the "new" physics subsume and organize the limited-case laws of Newtonian physics. These operations would be expected in adults who go beyond formal operations.

While that theory-based thinking about the nature of postformal operations was pointing toward the existence

of relativistic operations, another line of thought was also forming for me. Piaget's theory is rather deficient in describing the development of interpersonal understanding, i.e., how we know the nature of relations that exist between ourselves and others. For a long time I'd been curious about this particular cognitive development since social understanding seems to be one type of cognitive process that increases in adulthood and old age. "Knowing other persons and interpersonal relations" are also skills mentioned by adults when one asks them "what is intelligent behavior for a mature adult?"---data that increased my interest. As I probed childrens' and adults' explanations of how they come to know interpersonal relations I began to see orderly stages (which I will not discuss today) in the growth of that knowledge and a final stage which was once again amazingly like relativistic operations---more data for my perusal.

While that thinking and data-gathering was taking place, my interest in group dynamics, as expressed in dialogues among group members, led to additional exploratory data. These data supported the existence of relativistic operations and pointed to cognitive effects on group development, on shared interpersonal understanding, and even on group change.

My curiosity having been stimulated by this apparent convergence of Piagetian theory, ideas in the "new" physics, and social cognitive data, I reexamined some older problem-solving data and I presented some problems demanding

combinatorial reasoning to adults. I then performed both qualitative and quantitative analyses on their reasoning. I wanted to explore whether the success rates, strategies, and styles used on these problems differed between age groups and individuals or demonstrated operations forming a pattern other than a concrete or formal one. If a new pattern appeared, was it like relativistic operations? One of the things I found was a tendency for adults to use what I was calling relativistic operations in solving these complex, potentially formal operations problems, especially for social problems. This constituted further support.

So, I found a number of lines of thinking and a number of sources of data leading me to the same place. Questions about Piagetian theory and ecologically valid aging research and adult development might all have an answer in the skills involved in a reconceptualization called "relativistic operations" which permits complex reconceptualizations to take place.

Upon examing some work in information processing (especially that of Newell & Simon, 1972), it became clear that what I was examining was "how respondents made decisions about which knowledge elements and processes in the task environment (that is, the potential set, in the problem solver's view, of admissible information) to admit to official consideration in problem space (that is, the actual set of admissible information used) before solving a problem." This was an aspect of problem solving which had received little attention in Newell and Simon's model because their

problems were highly structured and the choice of elements to include in problem space was a foregone conclusion. With everyday problems, the potentially-usable elements in the task environment are much more numerous, and selection is an important factor in creation of multiple effective solutions. So I began thinking of my "relativistic operations" using the concepts of Piagetian theory and the information processing approach of Newell & Simon.

Definition of Relativistic Operations

Relativistic operations are logical operations which can be used as a system to relate, order, and select as more useful one of many mutually contradictory but "true" formal operational systems. Therefore they are a higher level of processing and are post-formal. They include an element of necessary subjectivity or self-reference. They permit the kind of logical thinking that characterizes the "new" physics. They permit the kind of logical thinking that makes it possible to analyze complex relations like interpersonal relations, relations which we are bringing into existence from moment to moment as we interact with others.

The truth of any proposition is usually decided by moving one step back in systems, "jumping out", so that, from the far reference point, one can judge the truth or falsity of a statement. Human knowing is limited by definition; no system can know itself (Hofstadter, 1979). Relativistic operations permit logical thinking in the

situations (which mature adults face daily) where one can go no further back (interms of reference points) in creating criteria for truth or falsity (Tarski;see Popper, 1972). Your decision about higher-level truth rules is ultimately a function of your lower-level decisions which are based on these rules (within the limits of real feedback maximizing true outcomes--Popper, 1972). Relativistic operations permit us to logically maximize "true" outcomes in a situation of truth criterion uncertainty by allowing for self-referential higher-order logical decisions (Heisenberg, 1958). The outcomes of these higher-level metatheoretical-system self-referential truth criteria decisions can then be tested by lower-level formal operations using the scientific method.

Relativistic operations seem to be involved in conscious reconceptualizations that let us select a new set of rules for interpreting a problem. Therefore they permit multiple-formal-operations solutions of a problem based on general case, overriding, self-referential rules. Some of the mechanisms involved seem to be these:

Insert Table 1 about here

In order to test the assumption that relativistic

post-formal operations are present in the thinking of mature adults who respond to the demand to "make all possible combinations," male and female volunteers in the Baltimore Longitudinal Study of Aging between the ages of 26 and 89 (Table 2) were interviewed. A modified clinical method was used in which standard problems were followed by probes to clarify responses (Table 3).

The focus of the interviews was problem solving. Six stimulus problems were presented in written form in random order; the two to be discussed here appear in Table 3.

Insert Tables 2 & 3 about here

Operational Definitions and Scoring of Relativistic Operations

Relativistic operations construct systems of formal operational systems to permit selection of one formal system among many where several could apply. Relativistic operations include the processes in Table 1, and are necessarily both logical (since they imply formal operations) and subjective (since they imply choice of a formal system).

Respondents are scored on abstract formal operations, alternative systems of formal operations (if appropriate), and, most important, relativistic operations in Table 1. Problems demand combinatorial reasoning with either 2 or 3 variables involved. Problems include totally abstract demands, like making pairs of letters, and fairly realistic scenarios with embedded abstract demands.

A subject is considered "abstract formal operational" on a problem if the following conditions are present: the correct numerical or verbal answer is given to the abstract problem (e.g., "15 pairs"), and the subject correctly describes how the answer was obtained, outlining the variables manipulated and the strategy used to make exhaustive combinations.

A subject might pass the abstract formal demands and also give an alternative formal logical solution to the same problem considered from a different point of view. For example, after passing the bedroom problem on an abstract level the subject might go on to point out that in real life "the grandfather must live with someone," and, "under those conditions, two of the 6 possible combinations would not be logical in real life." Alternative real-life solutions like these are scored for formal operations. If the variables and strategy are outlined and the correct logical answer in terms of the variables at hand is given, the subject passes. In the example above, the logically correct answer would now be 4 combinations because the additional variable of "grandfather must have a companion" is introduced.

In addition to scoring the responses for presence or absence of abstract or real-life formal operations, they are scored for presence or absence of relativistic operations listed in Table 1. The occurrence of more complex processing may be a function of age and problem

characteristics. Evidence that many respondents examine more than one formal system is in Figure 1 which describes approaches to the BR problem.

Insert Figure 1 about here

Operations

Evidence for use of relativistic operations is in Table 4 by age, sex, and problem. For BR, many respondents use relativistic operations especially problem definition, parameter setting, and pragmatic metatheory choice, though no one uses them all and articulates that process to us. The ABC problem is much less likely to elicit use of operations in Table 1, as seen in Table 4. (Another study using more demanding social formal operational problems is producing results like those for BR).

Insert Table 4 about here

Styles

Individuals had definite styles in terms of use/nonuse of relativistic operations, of formal operations, and of individual relativistic operations. For example, some never reconceptualized by using a second set of a priori's; others always did. Some acknowledged a large task environment and used it in their problem space; others examined only one or two items of knowledge or processes and seemed aware of no more; still others saw a large number of possibilities but did not use them effectively. Problems involving people and interpersonal relations were more often the occasion for relativistic operations use. The respondent

approaching the problem might see it as an occasion for categorization, or for hypothetical deductive reasoning, or for application of a well-known algorithm, or for use of relativistic operations.

It has never been clear how individuals decide what to include in problem space (that is, which knowledge elements or processes to admit to consideration) when processing information (Newell and Simon, 1972). In my data I see some clues. Several characteristics could routinely be found in the task environment (that is, among the potential [in the view of the problem solver] knowledge or processes useful for solving the problem) or in the respondent when problem space was large, when relativistic operations were used, or when several valid or "true" solutions were accepted.

Insert Table 5 about here

These other characteristics were usually present when respondents selected one and only one formal solution as better (more "true") than others and rejected other solutions, thereby constricting the task environment into smaller problem space:

Insert Table 6 about here

"Thinking out loud" procedures recommended by Giambra and Arenberg (1980) are now being used to describe each of

the considerations made by problem solving respondents with qualitatively differing "strategies" for processing problem information. Of course more work is being done on all aspects of the ideas I've raised.

Summing Up

I promised to assist in the search for missing links between cognition and everyday problem solving. I proposed that an area that should be examined (one I was examining) concerned mechanisms for complex cognitive reconceptualizations. I suggested that seldom-examined complex processes for major reconceptualizations---processes I called relativistic operations---could be the link between Piagetian theory, information processing theory, logical thought in the new physics, and mature adults' problem solving in everyday social situations.

I would like to recapitulate my three main points. First, a qualitatively different set of thinking skills or operations---an everyday sort of "theory of relativity"---that I call "relativistic operations" seems to be used by many mature adults to solve everyday logical problems. Second, examining these skills may provide us with missing links and with interesting developments for at least two cognitive models---Piagetian theory and information processing. Third, using an information processing model, these relativistic operations are expressed at the point at which an individual decides which information and decision rules to include or exclude from problem space.

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Table 1

Some Relativistic Operations

1.	Metatheory shift:	changing a priori considerations from one set to a conflicting set
2.	Problem definition:	focusing on defining the problem
3.	Process/product shift:	deciding to solve for a dynamic or for a particular content solution
4.	Parameter setting:	defining the limits of the problem factors
5.	Pragmatism:	evaluating abstract solutions and practical solutions separately in terms of usefulness, difficulty
6.	Multiple solutions:	being aware that a multi-caused problem most likely has several "correct" solutions
7.	Multiple causality:	utilizing multifactorial explanations and probablistic predictions
8.	Paradox:	being aware that a problem can be read in two conflicting ways

Table 2

Age and Sex of Participants

	Male	Female	
Age (at last birthday)			
Young: 20-39	8 (10%)	7 (9%)	Total = 15 (19%)
Middle aged: 40-59	13 (16%)	10 (12%)	Total = 23 (29%)
Young old: 60-69	15 (19%)	5 (6%)	Total = 20 (25%)
Old old: 70 or older	15 (19%)	6 (7%)	Total = 21 (26%)
	51 (64%)	28 (35%)	79 (100%)

Table 3

Problems

PROBLEM ABC

Six letters of the twenty-six letters of the alphabet appear below. Imagine that you are making pairs of the letters, writing down all the possible ways of putting two different letters together. How many pairs will you have when you make all possible pairs of the six letters? (Remember, although any letter will appear several times in different pairs the same letter should not appear twice in the same pair: ~~BB~~ BC BD). Use these letters: A B C D E F

PROBLEM BR

A small family consisting of a mother in her 40's and a ten-year old girl live in a small two-bedroom house in Detroit. The mother occupies a large well-decorated bedroom (that sleeps one) and the child uses a smaller bedroom (that sleeps one). This summer the family learns that a grandfather who lives alone in a one-bedroom (sleeps one) apartment two blocks away can no longer live alone. He might move in with the family. Under the circumstances, what are all the possible ways that three persons can use the three available bedrooms in the house and apartment?

Table 4

Percentage of Respondents Giving Evidence of Post-Formal Operations, BR Problem, by Age and Sex

	Total BR	Young		Middle Aged		Young Old		Old Old	
Operation Element	(N=79)	F(N=7)	M(N=8)	F(N=10)	M(N=13)	F(N=5)	M(N=15)	F(N=6)	M(N=15)
1. Metatheory choice	35%	57%	75%	20%	23%	---	40%	16%	40%
2. Problem definition	93%	85%	100%	100%	84%	100%	93%	83%	100%
3. Process/product shift	20%	---	25%	10%	7%	60%	40%	16%	13%
4. Parameter setting	92%	100%	100%	100%	76%	100%	93%	83%	93%
5. Pragmatism	73%	100%	87%	50%	61%	40%	86%	33%	93%
6. Multiple solutions	37%	71%	62%	40%	23%	40%	33%	16%	33%
7. Multiple Causality	31%	14%	12%	20%	46%	80%	40%	16%	26%
8. Paradox	13%	14%	12%	10%	7%	---	13%	33%	20%

Table 5

Some Characteristics of Task Environment

Defined by Subject, or of Respondent per se

When Problem Space Effectively Used by Subject Was Large

1. Multiple interpretations of context
2. Large memory capacity
3. Problem interpreted as social
4. Problem considered important
5. Previous use of relativistic operations in other problems
6. Evaluation that several solutions are "workable"
7. Multiple goals expressed
8. Can "jump out of system" in hierarchy of nested concepts
9. Several solutions are mutually mappable
10. Respondent separates process and state considerations
11. Search for general laws which hold true across multiple contradictory contexts

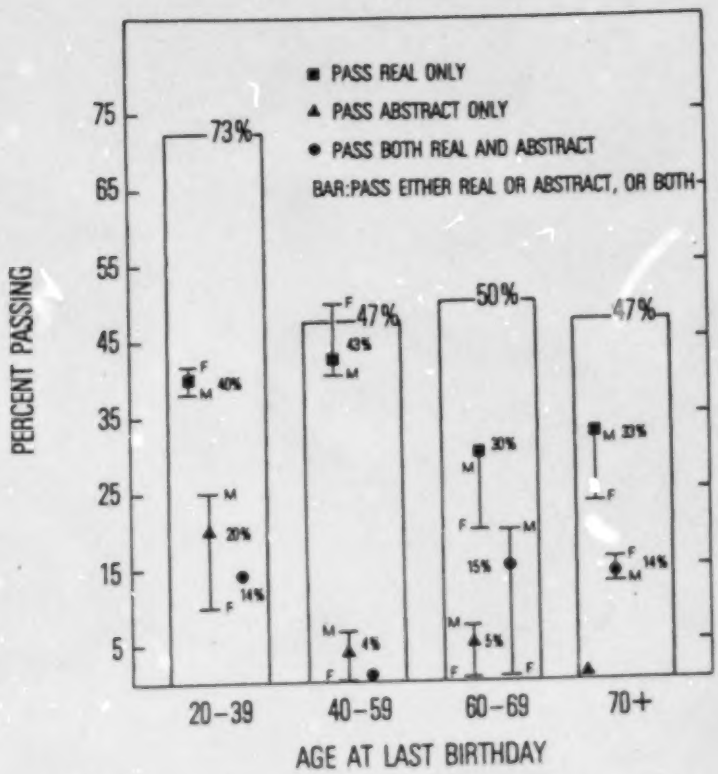
Table 6

Some Characteristics of Task Environment Defined by Subject, or of Respondent, per se When Problem Space Is Large But Portion Effectively Used is Small

1. Judgement that some information or process is not usable due to higher-level cognitive considerations
2. Problem judged unimportant
3. Judgement that only one solution is ever correct
4. Previous use of only this portion of information
5. Rejection of other information on emotional grounds (e.g., one is too hard to consider)
6. One goal
7. Previous experience used only limited information
8. Some alternative information or processes are better mapped to first choice than others

Figure 1 Caption

Varieties of Formal Solutions Used on BR, by Age.


PASS REAL ONLY
PASS ABSTRACT ONLY
PASS BOTH REAL AND ABSTRACT
BAR:PASS EITHER REAL OR ABSTRACT, OR BOTH
PERCENT PASSING
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47%
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60-69
70+
AGE AT LAST BIRTHDAY